Renewable and Sustainable Energy Reviews 16 (2012) 532–542

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on energy pattern and policy for transportation sector in Malaysia

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ARTICLE INFO

Article history:
Received 31 December 2010
Accepted 23 August 2011
Available online 1 October 2011

Keywords:
Transportation
Biodiesel
Energy policy
Fuel consumption
Emissions
Malaysia

ABSTRACT

Transportation has dominated global fuel consumption and greenhouse gas emissions have risen in an alarming rate. Gasoline and diesel consumption for road transport have a faster growing rate than other sector and the trend appeared to be rapidly moving upwards in the near future. This has caused much concern in many countries including Malaysia to improve the sustainable energy of this sector. The focus of this paper is to analyze the trends of energy pattern and emission of road transport in Malaysia. On top of that, the review of prospective policies such as fuel economy standards and fuel switching to natural gas as well as biodiesel are summarized in this study. The study found that there is an urgent need to adopt suitable energy policy to balance the energy demand and reduce emission in this sector. This study serves as a guideline for further investigation and research in order to implement and improve the transportation sector.

Contents

Abbreviations: CAFE, Corporate Average Fuel Economy; *CF*, conversion factor (1 toe = 41.868 GJ); CI, compression ignition; CNG, compressed natural gas; *EF*, emission factor; *f*, fuel type *f*; *FC*, fuel consumption; HC, hydrocarbon; *i*, in the year *i*; IANGV, International Association for Natural Gas Vehicles; *j*, emission type *j*; LNG, liquefied natural gas; NEDC, New European Drive Cycle; NGV, natural gas vehicles; SI, spark ignition; TEU, Twenty-Foot Equivalent Unit; *TM*, total emission.

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doi:10.1016/j.rser.2011.08.019

1. Introduction

Transportation sector is one of the major components of globalization and makes a vital contribution to the economy. Besides, it plays a curial role in daily activities around the world. Unfortunately, this activity is major energy consumption and use most of the limited non-renewable energy that creates a negative impact to living environment. On top of that, transportation sector is responsible for a large and growing share of emissions that affects global climate change [1]. One of the primary concerns will be the greenhouse gas (GHG) emission of CO_2 and air pollutants like NO_x and particulates. CO_2 emissions generated by the transportation sector have been causing much concern among the scientific community worldwide due to its rapid growth rates. At the moment, the transportation sector accounts for 13.5% of global warming [2]. Indeed, transportation has the fastest growing carbon emissions of any economic sector. Proliferating numbers of automobiles are the key reasons as more than 600 million passenger cars are now on roads around the world.

The global final energy consumption was growing from 4676 million tons of oil equivalent (Mtoe) since 1973 to 8429 Mtoe in 2008 as shown in Table 1 [3]. Transportation sector occupied 1081 Mtoe (23.1%) in 1973 and risen significantly to 2300 Mtoe which is 27.3% of the total global energy consumption in 2008. The main reason for the increase in transport sector is the continuing growth in household incomes and number of vehicles [4].

Global CO_2 emissions increased from 21 billion tons in 1990 to 29.4 billion tons of CO_2 in 2008. Within the total world emissions, 41% was originated from China and the United States, as these two countries alone produced 12.1 billion tons of CO_2 in 2008. On top of that, transportation sector contributed 6.6 billion tons of CO_2 which is 22.5% of total CO_2 emissions in 2008 as shown in Table 2 [5]. It remains the second biggest emitting sector over the period. Table 2 shows the CO_2 emission for few selected region and countries. However, Fig. 1 shows emission trends for different models of transportation system [6].

Global demand for transport appears unlikely to decrease in the foreseeable future as the World Energy Outlook projects that it will grow 45% by 2030 [7]. Policy makers should first and foremost consider measures to encourage or require improved vehicle efficiency to limit the emissions from this sector. Therefore, in order to utilize the energy consumption and emission reduction for transportation, it is important to analyze the energy pattern of transportation sector. This paper is focused on the trend of energy and emission pattern for transportation sector in Malaysia. Apart from that, a review of recommended strategies and policies for transportation sector are summarized in this study.

2. Transportation fleet pattern in Malaysia

2.1. Road transport

Malaysia's population is about 27.73 million and the gross domestic product (GDP) grew at an average 6% over the last 20 years [8]. As such, being a fast industrializing and boosting of economy country, transportation makes a vital contribution to the economy and plays a curial role in daily activities. This is one of the factors that increase motor vehicle ownership. The motor vehicle ownership has increased significantly every year and reached double of the number for every 10 years. Table 3 shows the road transport vehicles in Malaysia [9]. The road transport vehicles have increased dramatically from 4.5 million vehicles in 1990 to 18 million vehicles in 2008 which grow almost 4 times with the annual growth rate of 8%. The highest growth rate is in year 1996 and 1997 at 11.43% and 11.25% respectively. Apart from that, Fig. 2 illustrates the motorization rates in Malaysia and the total vehicle motorization rates have been increasing steadily from 260 in year 1990 to 660 in 2008 per 1000 populations.

One of the solutions for transportation is by using public transport because it is the key player in maintaining congestion at reasonable levels on the roads. Public transport makes use of road space more efficiently and consumes less fuel than the passenger car with same passenger-km. However, the average usage of public transport in the city is merely 16% in Malaysia and is the lowest figure among the countries in Asia. Table 4 shows the mode split between private and public transport mode for year 1990–2008. There is a big gap between proportion of private car and public transport with public transport share appears diminishing trend over the year. The proportion of public transport is only 1.9% in 2008 and private passenger car occupies 98.1%. Public transport is a solution for environmental pollutant and road traffic. Therefore, government should improve and promote the public transport for wider usage to meet the goal of reducing greenhouse gasses reduction.

Table 1
Global final energy consumption by sector [3].

Sector	1973		2008	
	Mtoe	Share (%)	Mtoe	Share (%)
Industry	1544.6	33.0%	2345.1	27.8%
Transport	1081.2	23.1%	2299.4	27.3%
Agricultural/commerce/civil	1764.6	37.7%	3036.9	36.0%
Non-energy use	285.3	6.1%	747.1	8.9%
Total	4675.7	100.0%	8428.5	100.0%

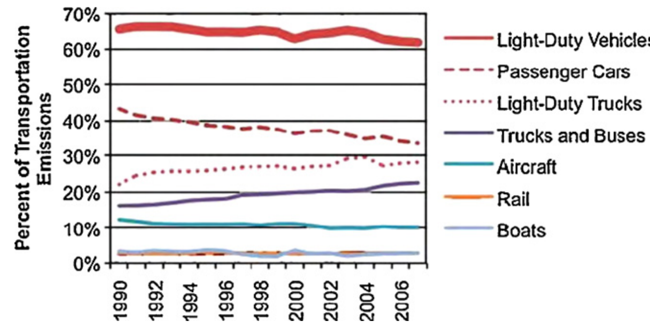


Fig. 1. CO_2 emissions from transportation sector by mode [6].

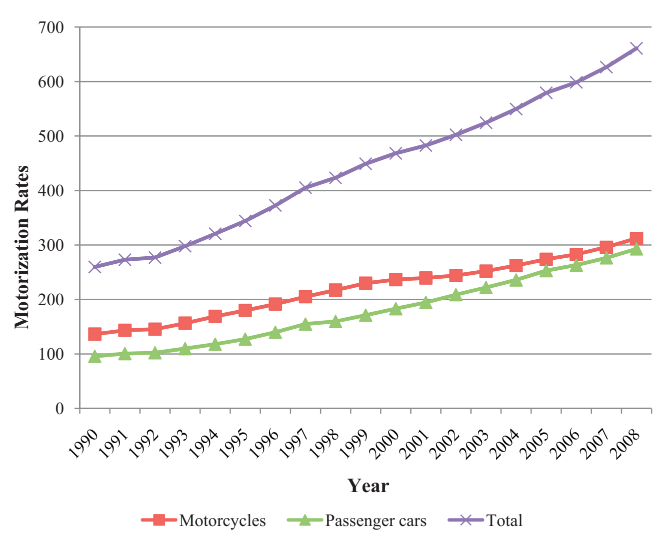


Fig. 2. Motorization rates from 1990 to 2008 in Malaysia.

Table 2
Global CO_2 emission by major region and sector in 2008 (million tons) [5].

Regions	CO_2 emission by sector					Total CO_2
	Electricity	Industry	Transport	Other[a]	Residential	
China	3136.9 (47.9)[b]	2174.5 (33.2)	456.9 (7.0)	496.2 (7.6)	285.9 (4.4)	6550.4
USA	2403.4 (42.9)	633.1 (11.3)	1691.6 (30.2)	535.1 (9.6)	332.7 (5.9)	5595.9
Latin America	215.9 (20.2)	279.6 (26.2)	361.8 (33.9)	147.9 (13.8)	63.0 (5.9)	1068.2
Europe	1063.9 (33.0)	514.3 (16.0)	850.5 (26.4)	391.4 (12.1)	402.8 (12.5)	3222.9
OECD	4992.0 (39.5)	1819.1 (14.4%)	3386.5 (26.8)	1447.7 (11.5)	984.4 (7.8)	12,629.7
World total	11,987.9 (40.8)	5943.6 (20.2%)	6604.7 (22.5)	2940.2 (10.0)	1905.1 (6.5)	29,381.5

[a] Other includes commercial, agriculture and other emissions not specified elsewhere.
[b] Value inside the parenthesis is in %.

Table 3
Road transport vehicles in Malaysia [9].

Year	Motorcycles	Passenger cars	Buses	Taxi/hire cars	Goods vehicles	Others	Total	Growth rate (%)
1990	2,388,477	1,678,980	24,057	35,405	288,479	132,016	4,547,414	9.44
1991	2,595,749	1,824,679	26,147	38,477	313,514	143,472	4,942,038	8.68
1992	2,762,666	1,942,016	27,827	40,953	333,674	152,698	5,259,834	6.43
1993	2,970,769	2,088,300	29,924	44,040	358,808	164,199	5,656,040	7.53
1994	3,297,474	2,302,547	33,529	47,512	393,833	178,439	6,253,334	10.56
1995	3,608,475	2,553,574	36,000	55,002	440,723	203,660	6,897,434	9.34
1996	3,951,931	2,885,536	38,965	59,456	512,165	237,631	7,685,684	11.43
1997	4,328,997	3,271,304	43,444	62,119	574,622	269,983	8,550,469	11.25
1998	4,692,183	3,452,852	45,643	64,632	599,149	286,898	9,141,357	6.91
1999	5,082,473	3,787,047	47,674	65,646	642,976	304,135	9,929,951	8.63
2000	5,356,604	4,145,982	48,662	66,585	665,284	315,687	10,598,804	6.74
2001	5,609,351	4,557,992	49,771	66,565	689,668	329,198	11,302,545	6.64
2002	5,842,617	5,001,273	51,158	68,139	713,148	345,604	12,021,939	6.36
2003	6,164,958	5,428,774	52,846	70,933	740,462	361,275	12,819,248	6.63
2004	6,572,366	5,911,752	54,997	75,669	772,218	377,835	13,764,837	7.38
2005	7,008,051	6,473,261	57,370	79,130	805,157	393,438	14,816,407	7.64
2006	7,458,128	6,941,996	59,991	82,047	836,579	411,991	15,790,732	6.58
2007	7,943,364	7,419,643	62,308	84,742	871,234	432,652	16,813,943	6.48
2008	8,487,451	7,966,525	64,050	90,474	909,243	454,158	17,971,901	6.89

2.2. Rail transport

The railway system has progressed to nationwide single track network of 1700 km spanning the whole of Peninsular Malaysia [10]. Rail transport passengers and freight traffic from year 1992 to 2008 are shown in Table 5 [11]. In terms of passenger number, the passengers decreased from 7.61 million in 1992 to 4.27 million in 2008 while the passenger-km decreased to 1512 million in 2008. On the other hand, the freight traffic increased from 3.55 million tons to 5.23 million tons in 2008 while the number of container increased significantly with an annual growth of 12.4%.

Table 4
Proportion trend of private and public transport vehicles for road transport.

Year	Private cars		Public transport vehicles		
	Passenger cars	Share (%)	Buses	Taxi/hire cars	Share (%)
1990	1,678,980	96.58	24,057	35,405	3.42
1991	1,824,679	96.58	26,147	38,477	3.42
1992	1,942,016	96.58	27,827	40,953	3.42
1993	2,088,300	96.58	29,924	44,040	3.42
1994	2,302,547	96.60	33,529	47,512	3.40
1995	2,553,574	96.56	36,000	55,002	3.44
1996	2,885,536	96.70	38,965	59,456	3.30
1997	3,271,304	96.87	43,444	62,119	3.13
1998	3,452,852	96.91	45,643	64,632	3.09
1999	3,787,047	97.09	47,674	65,646	2.91
2000	4,145,982	97.30	48,662	66,585	2.70
2001	4,557,992	97.51	49,771	66,565	2.49
2002	5,001,273	97.67	51,158	68,139	2.33
2003	5,428,774	97.77	52,846	70,933	2.23
2004	5,911,752	97.84	54,997	75,669	2.16
2005	6,473,261	97.93	57,370	79,130	2.07
2006	6,941,996	97.99	59,991	82,047	2.01
2007	7,419,643	98.06	62,308	84,742	1.94
2008	7,966,525	98.10	64,050	90,474	1.90

2.3. Air transport

The main air transportation system in Malaysia includes commercial airlines and air freight carriers. Table 6 shows air traffic included total passenger, freight and commercial aircraft movement by air transport in Malaysia [11]. Commercial aviation accounted for 48.3 million passengers in year 2008. The freight of air transport increased drastically from 285 ktons in 1991 to 1039 ktons in 2006 but dropped back to 922 ktons in 2008. However, commercial aircraft movement increased steadily throughout the year.

2.4. Mode of transportation

In terms of number of passenger and freight carried, road transport is still leading among the transportation modes in Malaysia. Fig. 3 and Fig. 4 illustrate the mode of transportation allocation for passenger and freight respectively [12]. There are more than 94% of passengers and 96% of cargo carried by road transport. The rail passenger is about 4.7% while air transport served 0.5% of total passengers. However, the cargo carried by maritime, rail and air transport were 2.3%, 1.2% and 0.1% respectively.

3. Energy consumption and emission in Malaysia

3.1. Energy consumption

In Malaysia, the final energy use has risen at an annual growth rate of 6% from year 2000 to 2008 and reached 45 Mtoe in 2008. A

Table 5
Rail passenger and freight traffic in Malaysia [11].

Year	Passenger		Freight		Container TEU[a]
	Number ('000)	Passenger-km ('000,000)	Tons ('000)	Tons-km ('000,000)	
1992	7614	1859	3550	1081	93,192
1993	6510	1553	4196	1157	95,569
1994	5426	1348	5164	1463	121,450
1995	5146	1270	5249	1416	137,137
1996	6111	1370	5405	1417	124,588
1997	5375	1492	5106	1337	135,217
1998	4924	1397	3695	992	112,133
1999	4344	1316	3845	907	106,744
2000	3825	1220	5481	916	255,312
2001	3511	1181	4150	1094	149,669
2002	3437	1123	3741	1107	262,478
2003	3362	1018	4608	886	272,864
2004	3628	1139	4962	1032	302,736
2005	3675	1181	4031	1178	310,011
2006	3794	1237	4440	1402	339,037
2007	3714	1309	4670	1355	333,688
2008	3971	1468	4824	1350	203,939
2009	4267	1512	5230	1384	266,722

[a] TEU: Twenty-foot Equivalent Unit.

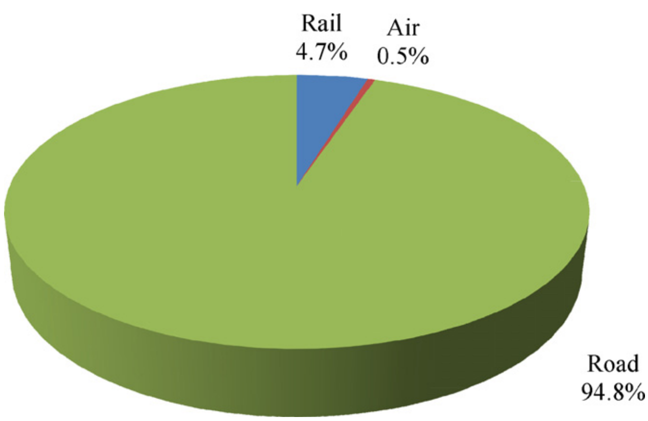


Fig. 3. Proportion of passenger by transportation type.

huge portion of total energy is consumed in industrial and transportation sector. The transportation sector alone accounted for 36% of total energy use in 2008 as shown in Fig. 5 [13]. The increased use of energy raised serious concerns in the Malaysian government about the need to overcome heightened energy expenditure by promoting the end-use energy efficiency. On top of that, transportation sector is highly dependent on petroleum products as the source of energy. Fig. 6 shows the petroleum products and more than 70% of

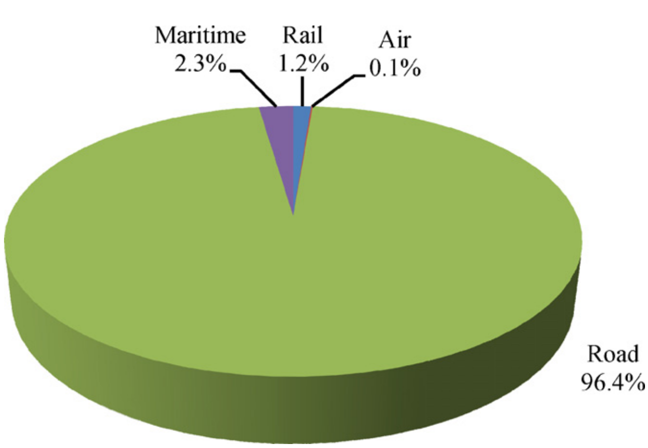


Fig. 4. Proportion of freight by transportation type.

Table 6
Air transport's traffic in Malaysia [11].

Year	Passenger ('000)	Freight (tons)	Commercial aircraft movement
1991	19,952	284,690	304,975
1992	21,745	291,385	365,750
1993	22,880	312,045	372,658
1994	24,192	381,410	383,722
1995	26,340	482,031	406,338
1996	28,873	541,417	441,596
1997	31,275	617,028	425,825
1998	27,008	524,766	413,237
1999	28,323	640,981	386,341
2000	31,663	762,378	381,413
2001	31,387	777,626	394,887
2002	32,680	782,993	412,508
2003	33,058	838,377	415,280
2004	39,751	927,322	454,969
2005	41,760	968,354	469,655
2006	42,916	1,039,361	462,260
2007	45,874	978,640	451,334
2008	48,272	922,397	496,271

crude oil products are diesel and petrol which is two main fuels for transportation in Malaysia.

In 2008, Malaysia has proven oil reserves of 5.46 billion barrels and 68% are located in East Malaysia Sabah and Sarawak [14]. Malaysia's crude oil production has declined in recent years and the average oil production is around 690 thousand barrels per day in 2008. When the production rate is consistent at around 700

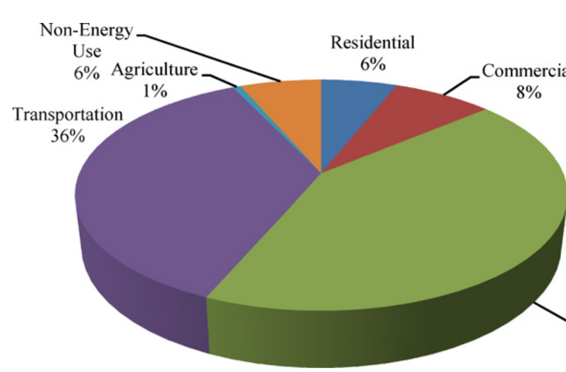


Fig. 5. Final energy consumption by sector in 2008.

Table 7
Energy use by transportation sector in Malaysia (ktoe) [10,13].

Year	Petrol	Diesel	ATF and AV gas	Fuel oil	Natural gas	Electricity	Total
1995	4477	2168	1160	17	5	0	7827
1996	5161	2417	1335	32	4	1	8950
1997	5574	3106	1439	75	5	1	10,200
1998	5849	2311	1619	9	4	1	9793
1999	6778	3174	1424	13	0	4	11,393
2000	6378	4103	1574	4	7	4	12,070
2001	6820	4534	1762	5	14	5	13,140
2002	6940	4680	1785	4	28	4	13,441
2003	7352	5019	1852	3	40	5	14,271
2004	7867	5398	2056	4	54	6	15,385
2005	8138	5132	2010	4	95	5	15,384
2006	7838	4726	2152	3	120	5	14,825
2007	8549	4859	2155	3	147	4	15,717
2008	8788	5283	2112	3	194	15	16,395

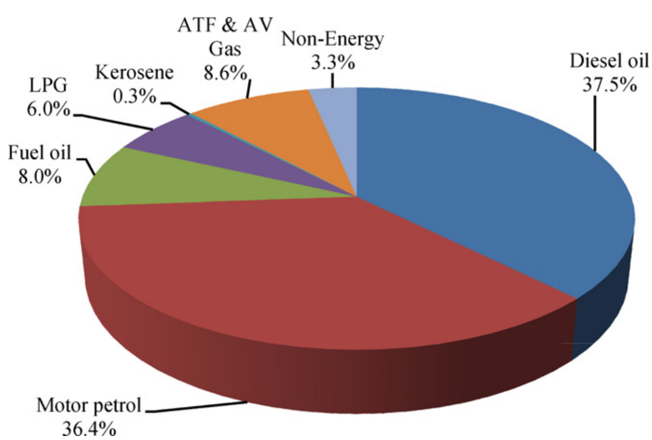


Fig. 6. Energy consumption of petroleum products in 2008.

thousand barrels per day, the ratio between reserve and production of 21 indicated that Malaysia's oil reserves will be exhausted in next 21 years [15]. In order to reduce huge demand of fossil fuel in transportation sector the government Malaysia introduced National Biofuel Policy in 2006. Hence, the government's focus is on ensuring a sustainable energy supply by enhancing energy efficiency and increasing energy sufficiency which will reduce dependence on petroleum products by increasing the usage of biofuel and biodiesel [16].

The pattern of energy consumption by transportation sector based on fuel types in Malaysia is tabulated in Table 7 and illustrated in Fig. 7 [10,13]. Total energy use by transportation sector increased from 7.83 Mtoe in 1995 to 16.4 Mtoe in 2008. This high growth rate is more than double with an annual growth rate of 6.6% over the year. Fuel type used in transportation sector included petrol gasoline, diesel, aviation turbine fuel (AVF), aviation gasoline (AV gas), fuel oil, natural gas and electricity in Malaysia. The main energy consumption is from fossil fuel with the primary use is petrol, followed by diesel and ATF and AV gas. There are some changes in the pattern of energy use after year 2000 in which the amount of natural gas use increased to 194 ktoe in 2008. This is due to the government's policy in promoting natural gas as an alternative fuel for road transport.

Table 8
Potential environmental impact from fossil fuel by transportation sector [18].

Fuels	Emissions			
	CO_2 (kg/GJ)	SO_2 (g/GJ)	NO_x (g/GJ)	CO (g/GJ)
Petrol	72.79	0.46	111.72	2225.97
Diesel	73.99	0.47	257.64	97.20
ATF	72.00	22.99	307.88	139.67
NG	53.90	–	488.00	214.00

3.2. Emissions

The transportation sector which fully utilizes petroleum products is no doubt the main contributor in CO_2 emission [17]. In order to calculate the potential environmental impact, the emission factor for carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxide (NO_x) and carbon monoxide (CO) with different fuel types were collected and shown in Table 8 [18].

The annual emission is the summation of emission for all fuel type consumed by transportation sector. The emission factor as well as usage of electricity and fuel oil in transportation sector is very little compared to other fuel types and these are neglected in

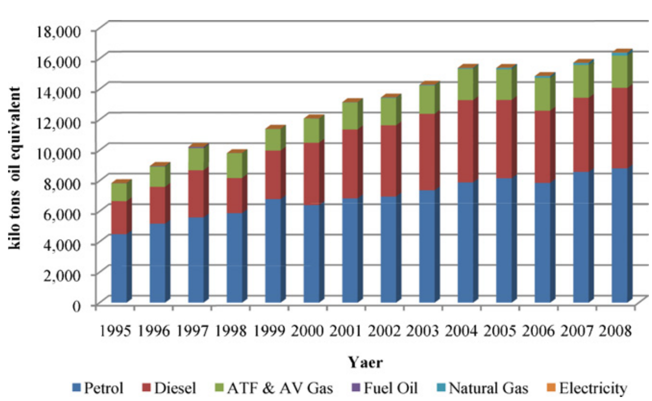


Fig. 7. Pattern of transportation sector energy use by fuel types.

Table 9
Total emissions by transportation sector in Malaysia (ton).

Year	CO_2	SO_2	NO_x	CO
1995	23,868,137	1245	59,382	432,894
1996	27,249,311	1432	67,503	498,668
1997	30,958,116	1554	78,228	540,579
1998	29,873,789	1716	73,238	564,017
1999	34,781,543	1564	84,297	652,933
2000	36,908,354	1719	94,524	620,374
2001	40,173,060	1917	103,807	664,483
2002	41,091,977	1944	106,526	676,521
2003	43,626,786	2023	113,218	716,797
2004	47,016,908	2237	122,631	767,654
2005	46,972,639	2192	121,274	791,927
2006	45,285,131	2315	117,833	763,370
2007	47,933,937	2335	123,183	830,433
2008	49,952,221	2306	129,281	854,603

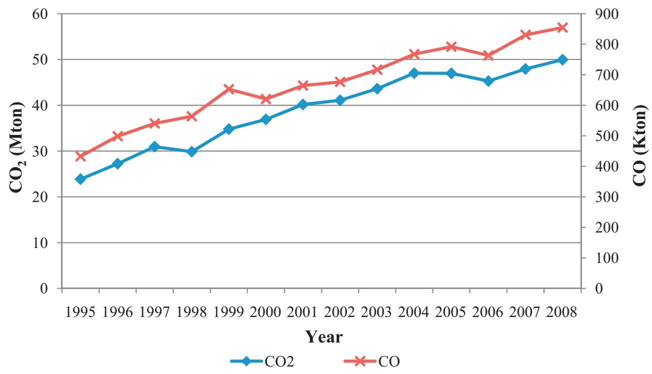


Fig. 8. Pattern of CO_2 and CO emissions by transportation sector in Malaysia.

this study. The total emission can be expressed by the following equation:

$$TM_i^j = CF_f^i \times \sum\nolimits_f FC_{i,f} \times EF_f^j \quad (1)$$

The total emission by transportation sector was calculated based on the data in Tables 7 and 8 using Eq. (1). The results are shown in Table 9 and the pattern of emission illustrated in Figs. 8 and 9. The CO_2, SO_2, NO_x and CO emissions had increased steadily over the past 13 years and still moving upwards. It is estimated about 50 million tons of CO_2 emissions in 2008 which is more than double from 1995 with annual growth rate 8.4%. This emission rate is considered relatively high among the developing countries. It is inevitable that pollutant emissions will continue to climb as long as fossil fuels remain as the main contributor in this sector. Therefore, it is important that accurate emission inventories are prepared for the transport sector in order to design and implement suitable technological and policy options for appropriate mitigation measures [19].

3.3. Fuel economy ratio

One of the most common ways to measure the fuel economy of transportation is the distance travelled per unit of fuel used in kilometers per liter (km/l). The average annual fuel economy ratio for road transport in Malaysia is shown in Fig. 10 [20]. As shown in Fig. 10, the fuel economy ratio is between in 7 and 7.7 km/l from year 1987 to 1999, and the ratio increasing steadily after year 1999 to 9.67 km/l in 2008. This increase is due to the technological advances improving the fuel economy of motor vehicles.

4. Policy recommendation

The increase in demand for the transportation is one of the causes that lead to higher rates of growth in demand for fossil oil.

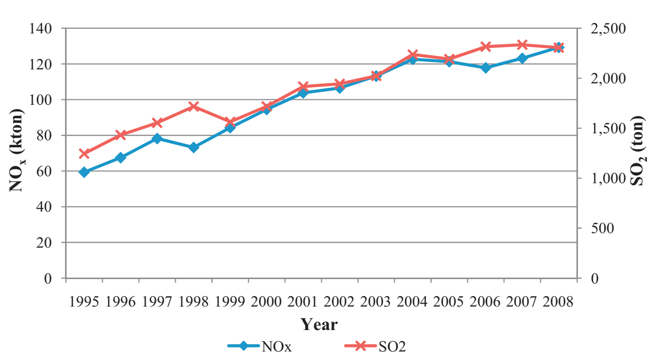


Fig. 9. Pattern of NO_x and SO_2 emissions by transportation sector in Malaysia.

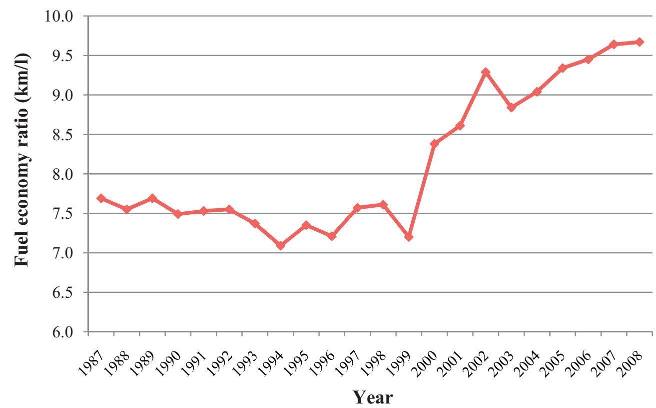


Fig. 10. Fuel economy ratio for road transport in Malaysia [20].

For most of the Asian countries, this growth is expected to be more rapid than the economy growth as a whole. However, there are not many policies around the world that have been implemented to reduce energy use by transport sector other than motor vehicles or road transport. Thus, there are many methods and policies that have been implemented for road transport vehicles to reduce fuel consumption in developed as well as in many developing countries. These policies include fuel economy standard, fuel economy label, fuel switching, fuel taxation, emission abatement and further improvements to vehicles.

4.1. Fuel economy standard

Automobile fuel economy standard is a minimum requirement for the energy performance of a motor vehicle that manufacturers must meet before it can be legally sold. It has been proven to be one of the most effective tools in controlling oil demand and greenhouse gas emissions from the transportation sector in many regions and countries around the world.

Many developed countries have established motor vehicle fuel economy or GHG emission standards. Those countries include United States, European Union, Japan, Canada and Australia. In addition, Taiwan has had proposed fuel economy standards for more than a decade while China and South Korea have recently adopted new vehicle fuel efficiency standards. Each standard's stringency is strongly influenced by the test procedure used to measure fuel economy or GHG emissions. Over the last several decades, Europe, Japan and the United States have developed unique test procedures reflecting local real world driving conditions [21]. Due to various historical, cultural and political reasons different regions have adopted different fuel economy standards. These standards might differ in stringency by their apparent forms, structures and by how the vehicle fuel economy levels are measured. The world fuel economy standard and implementation methods in some selected countries are summarized in Table 10 [22].

In the United States, the Corporate Average Fuel Economy (CAFE) regulation is the primary federal regulations intended to improve the average fuel economy of cars and light trucks. USA is a large automotive marketplace, policy actions governing fuel efficiency standard affected not only US manufacturers but also all vehicle manufacturers selling their product in the USA. Therefore, CAFE legislation had an impact on the economies of the European community and Japan. As the CAFE regulation has been successful at increasing automotive fuel efficiency standard over time, the purpose of the regulation of its initiation was to help reduce reliance on foreign oil [23]. CAFE started at 18 mpg in 1978 and remained stagnant at 27.5 mpg from 1989 until early 2009. The CAFE standard on passenger vehicles currently saves over 55 billion gallons of fuel

Table 10
Fuel economy standard and implementation methods in selected countries [22].

Country/region	Type	Measure	Structure	Test method	Implementation
United States	Fuel	mpg	Single standard	US CAFE	Mandatory
European Union	CO_2	g/km	Single standard	EU NEDC	Voluntary
Japan	Fuel	km/l	Weight-based	JC08	Mandatory
China	Fuel	l/100 km	Weight-based	EU NEDC	Mandatory
Canada	Fuel	l/100 km	Vehicle class based	US CAFE	Voluntary
Australia	Fuel	l/100 km	Single standard	EU NEDC	Voluntary
South Korea	Fuel	km/l	Engine size based	US CAFE	Mandatory
Taiwan	Fuel	km/l	Engine size based	US CAFE	Mandatory

annually in United States. The new CAFE standards apply to model years 2012–2016 for all passenger vehicles sell in the United States including cars, light trucks and SUVs. By 2016, automakers' passenger vehicle fleets must achieve a combined average fuel economy standard of 35.5 mpg for cars and 30 mpg for light trucks and SUVs. The new CAFE standards also aggressively exceed the target goal Energy Independence and Security Act of 2007 (EISA) passed by Congress, which required average fuel economy of 35 mpg by 2020 [24].

A decade ago, the European Union entered into a series of voluntary agreements with the associations of automobile manufacturers that sell vehicles in the European market to reduce CO_2 emissions. The average light vehicle CO_2 emissions in European industry were 15% below 1995 levels but did not achieve the140 gCO_2/km target set for 2008 [25]. The EU has agreed to set a mandatory target for passenger cars of 130 gCO_2/km by 2012. The Council expressed a desire to include a longer-term vehicle emissions target for 2020 within the context of an overall strategy to address climate change. In Canada fuel economy standard has been set by Transport Canada under voluntary Motor Vehicle Fuel Consumption Standard (MVFCS) program [26].

China recently approved regulations for new fuel economy standards for its passenger vehicle fleet to regulate the country's rapidly growing vehicle market [27]. China began implementing passenger car fuel economy standards in two phases beginning in 2005. Phase 1 fuel consumption limits resulted in a sales-weighted new passenger car average fuel consumption decrease of about 11% from 9 l/100 km to 8 l/100 km in year 2002–2006. However, Phase 2 limits in 2009, where the average fuel consumption of new passenger cars in China may drop by an additional 1% to approximately 7.9 l/100 km [28]. A Phase 3 standard fuel consumption standard for passenger vehicles approved technically in 2009 and will take effect in 2012. This standard aims to introduce advanced energy saving into passenger vehicles and reduce the average fuel consumption rate of new passenger vehicle fleet in 2015 to 7 l/100 km. The Phase 3 standard follows the evaluating system by specifying fuel consumption targets for sixteen individual mass-based classes [29]. Japan has established fuel efficiency targets for passenger and light commercial vehicles for each vehicle weight class. The targets represent fleet wide new vehicle consumption equivalent to 129 g CO_2/km for passenger vehicles by 2010. The majority of Japanese vehicles sold in Japan have achieved their class standard and revised target equivalent to 115 gCO_2/km established for 2015 [30].

The study found that implementing fuel economy standard for motor vehicles in Malaysia will provide significant amount of fuel and emission reductions [20]. As with implementation of fuel economy standards for passenger car in 2010, it can be saved up to 15 Gl of fuel by the end of the year 2018. Fig. 11 shows the comparison of fuel consumption with fuel economy standards and fuel consumption without standard (BAU). On the other hand, the potential CO_2 reduction will be 35.8 million tons in the same period [20]. Furthermore, implementation of fuel economy standard is one of the promising policy programs to conserve energy in a developing country like Malaysia. Policymakers should implement the mandatory fuel economy standard program. It is found that from the experience of many countries the mandatory program is more effective compared to a voluntary program. Therefore, it is very beneficial to introduce the fuel economy standard for motor vehicles in Malaysia in order to have the solution for oil dependence and GHG emissions reduction.

4.2. Natural gas vehicle

The scarcity of fossil fuel supplies in the long term and concerns about air quality in urban environments drive the current demand and research to alternative fuels besides fossil fuel. Natural gas is widely available, offers greenhouse gas reductions and produces fewer emissions compared to other traditional fossil fuels. Natural gas can be used either as compressed natural gas (CNG) or liquefied natural gas (LNG). Natural gas vehicles (NGV) are a significant part of the solution to oil shortages, global warming and air pollution. Today, more than 11.3 million NGVs are on the road and about 16.5 thousand natural gas refuelling stations are in operation worldwide [31]. Over the next 10 years, IANGV are projecting a three-fold increase to reach a target of 50 million NGVs on the road globally by 2020. Many countries have been using natural gas as a clean alternative to other automobile fuel with largest number in Pakistan (2.3 million), Argentina (1.8 million), Iran (1.7 million), Brazil (1.6 million) and etc. On top of that, in United States, India, Australia, Argentina and Germany there is widespread use of natural gas powered buses in public transportation fleets.

CNG has been used successfully to power the vehicles of various ranges from light delivery trucks to full size urban buses and it has been used in vehicles since 1930. Most of the NGV engines used today are converted from gasoline engines with gasoline as a stand-by and it produces about 10–15% less power than the same engine fuelled by gasoline. Another main drawback is the heavier fuel storage tank and vehicle range is compromised for avoiding very large storage tank.

There are a lot of researchers going on worldwide study on performance, emission and optimization of natural gas use in spark ignition (SI) and compression ignition (CI) engines. A comparative analysis on a gasoline and CNG fuelled retrofitted SI engine show that using natural gas can produce higher brake thermal

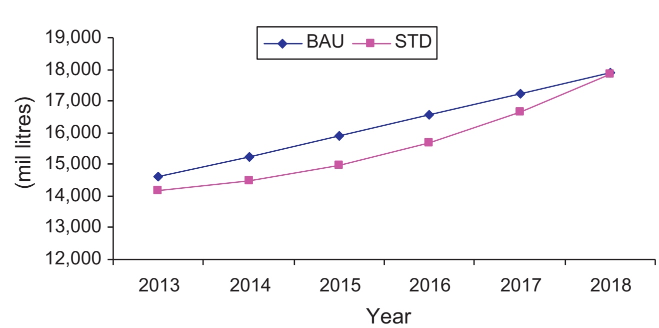


Fig. 11. Motor vehicle fuel consumption with and without standards [20].

efficiency and exhaust gas temperature but also increased NO_x emission by 40% over the speed range of 1500–5500 rpm at 80% throttle. However, other emission like unburned HC, CO, O_2 and CO_2 were significantly lower than those of the gasoline emissions [32]. The variable stroke technique can be used to improve the performance and emission characteristics of natural gas fuelled SI engines [33]. Saidur et al. [34] evaluated the effect of partial substitution of diesel fuel by the natural gas on performance parameters of a four-cylinder diesel engine. Natural gas is used to power CI engines via the dual-fuel mode, where a high cetane fuel is injected along with the natural gas in order to provide a source of ignition for the charge. Thermal efficiency levels are generally maintained with dual-fuel operation compared with normal diesel fuelled CI engine operation, and smoke levels are reduced significantly. At the same time, lower NO_x and CO_2 emissions, as well as higher HC and CO emissions compared with normal diesel CI engine operation. These trends are caused by the low charge temperature and increased ignition delay, resulting in low combustion temperatures [35]. The present study indicates that the CNG is a better choice as automobile fuel than the gasoline both economically and environmentally.

Malaysia currently produces 72.6 billion cubic meters natural gas and consumes only 26.7 billion cubic meters [13]. Hence, there is plenty of natural gas available for automotive use. The use of compressed natural gas was originally introduced for taxicabs and airport limousines during the late 1990s. However, the number of NGV in Malaysia is still very low compared with Pakistan, Argentina and Brazil. As fuel subsidies were gradually removed from year 2008, the subsequent 41% price hike on petrol and diesel led to a drastically increase in the number of new NGV in Malaysia. The number of NGV increased to 42 thousand vehicles in 2009 as shown in Fig. 12 [31]. National car maker Proton considered fitting Waja, Saga and Persona models with CNG kits by the end of 2008, while a local distributor of locally assembled Hyundai cars offers new models with CNG kits [36]. NGV is promoted by the government with incentives and legislation to encourage vehicles owner to use natural gas. Government's support for NGV development is reflected by the exemption of import duty and sales tax on NGV conversion kit. Therefore, it will reduce the capital cost of conversion for NGV, thus reducing the payback period.

4.3. Biodiesel

Biodiesel is the renewable energy derived from the reaction of vegetable oils or lipids as well as alcohol and has great potential to serve as an alternative to petro-diesel fuel in compression ignition (CI) engine. Commercially, these blends are named as B10, B20 or B100 to represent the volume percentage of biodiesel component in the blend with diesel fuel as 10, 20 and 100 volume percentage respectively. Currently, many countries around the world have explored and commercially used biodiesel blends for their vehicles such as US, Germany, Japan, Brazil, India and so on.

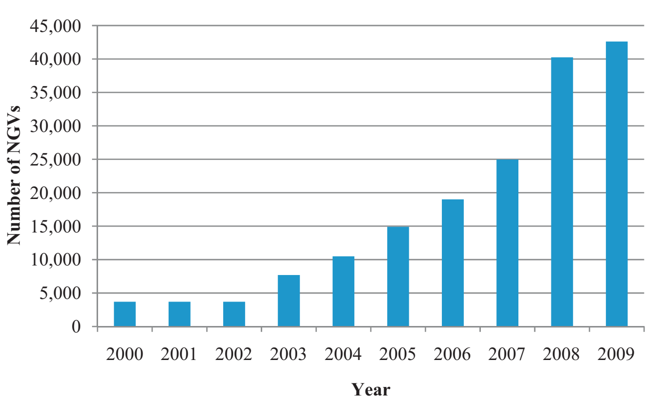


Fig. 12. Natural gas vehicles in Malaysia.

Table 11
Typical greenhouse gas emission saving for biodiesel.

Type of biodiesel	Typical GHG emission savings (%)
Palm oil	36
Palm oil (process with methane capture)	62
Soybean	40
Rapeseed	45
Sunflower seed	58

Biodiesel which has combustion characteristics similar to diesel and biodiesel blends has shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compare to diesel fuel [37]. Moreover, the engine power output and brake power efficiency was found to be equivalent to diesel fuel. Biodiesel and diesel blends can reduce smoke opacity, particulate matters, unburned HC, CO_2 and CO emissions but NO_x emission has slightly increased [38]. The typical greenhouse gas emission saving for main feedstock of biodiesel is shown in Table 11 [39]. However, the main drawback of biodiesel fuel is their high viscosity and low volatility, which causes poor combustion in diesel engines including formation of deposits and injector cocking due to poorer atomization upon injection into the combustion chamber. Those problems are challenges faced by engine manufacturers and researchers to overcome. Transesterification, chemical and thermal processes, blending and microemulsification of vegetable oils reduced the viscosity [40]. Esterification and transesterification reactions are the most favored reaction pathways to produce biodiesel. Any type of feedstock that contains free fatty acids or triglycerides such as vegetable oils, waste oils, animal fats and waste greases can be converted into biodiesel [41]. However, the final products must meet stringent quality specifications of ASTM D 6751 (American standard) or EN 14214 (European standard) before it can be accepted as biodiesel fuel. Technical properties of biodiesel are presented in Table 12 [42]. Biodiesel is a clear amber-yellow liquid with a viscosity similar to diesel fuel. Biodiesel is non-flammable with a flash point of 423 K as compared to 337 K for diesel. The source for biodiesel production is usually chosen according to the availability in each region or country. United States and European community are self-dependent in production of edible oil and even have surplus amount to export. Therefore, edible oil such as soybean and rapeseed are utilized for the synthesis of biodiesel. Similarly, palm oil and coconut oil are surplus in coastal area countries like Malaysia, Indonesia and Thailand have become the primary source

Table 12
Technical properties of biodiesel [42].

Common name	Biodiesel
Common chemical name	Fatty acid (m)ethyl ester
Chemical formula range	C_{14}–C_{24} methyl esters or $C_{15-25}H_{28-48}O_2$
Kinematic viscosity range (mm^2/s, at 313 K)	3.3–5.2
Density range (kg/m^3, at 288 K)	860–894
Boiling point range (K)	>475
Flash point range (K)	420–450
Distillation range (K)	470–600
Vapour pressure (mm Hg, at 295 K)	<5
Solubility in water	Insoluble in water
Physical appearance	Light to dark yellow, clear liquid
Odour	Light musty/soapy odour
Biodegradability	More biodegradable than petroleum diesel
Reactivity	Stable but avoid strong oxidizing agents

Table 13
Average oil yield for major oil sources.

Oil source	Oil yield (tons/ha/year)
Palm oil	3.85
Rapeseed	0.66
Sunflower	0.50
Soybean	0.45
Jatropha	1.59
Castor	1.19
Pongamia pinnata	0.25
Calophyllum inophyllum	4.68

for biodiesel. However, some countries are not self sufficient in edible oil and this has led them to explore non-edible seed oil as raw material for biodiesel. Non-edible oils used for feedstock mostly are the oils with higher free fatty acids such as jatropha (*Jatropha curcas*), castor, karanja (*Pongamia pinnata*), bintangor (*Calophyllum inophyllum*), etc. Table 13 shows the average oil yield of major oil sources for biodiesel feedstock [43,44]. As noted in the table, the highest oil productivity is palm oil which is about 8 times better than soybean oil and follows by calophyllum inophyllum oil.

The global potential volume of biodiesel production is 51 billion liters annually and top five biodiesel production countries are Malaysia, Indonesia, Argentina, United States and Brazil account for over 80% of the total production. Table 14 shows the list of top 10 countries ranked by overall biodiesel potential production volume with Malaysia far ahead among the rest. The feedstock for biodiesel for those nations are 28% for soybean oil, 22% for palm oil, 20% for animal fats, 11% for coconut oil and 5% for rapeseed, sunflower and olive oils each [45]. The potential market for biodiesel in road transport is projected to climb from 24 Mtoe in 2006 to 118 Mtoe in 2030 [7]. The rapid increase of biofuel in transportation is due to new national biofuel policy in several countries and high fossil oil price. Most of the growth comes from the United States, Europe, China and Brazil. Currently, ethanol accounts for larger share of the global biofuel market than biodiesel but the demand for biodiesel is grow faster than ethanol. The European Union and Asia are the fastest growth in demand for biodiesel. Several countries have aggressive policies in place for encouraging the production and use of biodiesel. Those countries have adopted policies such as tax exemptions, mandates and incentives for biodiesel. United States and Europe have notably move to promote more fuel efficient vehicles and encourage biodiesel supply contribute to the GHG reduction. In United States, the Energy Independence and Security Act 2007 mandate a significant increase in biofuels use by 2020. Besides, the European Union has a target for biofuels to meet at 10% of road transport demand by 2020 [7]. Table 15 shows the summary of biofuel policies in some selected countries. Most of the Southeast Asian countries including Malaysia are mainly focused on exporting the production of biofuel rather than utilization in their own countries.

As the world's largest palm oil producer and exporter, Malaysia is now looked upon as the pioneer palm biodiesel producer. Malaysia has embarked on a comprehensive palm biodiesel program since 1982. Biodiesel's status as a renewable energy source was further solidified in Malaysia when Envo Diesel was introduced through the National Biofuel Policy in 2006. Envo Diesel (B5) was a mixture of 5% blend of processed palm oil with 95% petroleum derived diesel [47]. However, Malaysian government has stopped the Envo Diesel project as it failed to market in 2008 as planned. On top of that, the government of Malaysia will implement the mandatory use of biofuel for vehicles in mid of 2011. The mandatory biofuel implementation involves 5% of palm methyl ester blended with 95% diesel and is part of the country's biofuel initiative under the B5 program. Apart from that, the biofuel implementation plan includes the RM43.1 million instigation of depot with inline blending facilities to be placed in Port Klang, the Klang Valley Distribution Terminal (KVDT) in Selangor, Negeri Sembilan and Tangga Batu, Malacca. Besides, replanting is widely seen as a way to enhance productivity and also to achieve Malaysia's long-term target at average of 35 tons of fresh fruit bunches and oil extraction rate of 25% by 2020 [48].

Table 14
Top 10 countries by absolute biodiesel production [45].

No.	Country	Volume (million liters)
1	Malaysia	14,540
2	Indonesia	7595
3	Argentina	5255
4	USA	3212
5	Brazil	2567
6	Netherlands	2496
7	Germany	2024
8	Philippines	1234
9	Belgium	1213
10	Spain	1073

Table 15
Summary of biofuel policies in some selected countries [7,46].

Country	Biofuel policy
Brazil	40% rise in ethanol production, 2005–2010; mandatory blend of 20–25% anhydrous ethanol with petrol; minimum blending of 3% biodiesel to diesel by July 2008 and 5% (B5) by end of 2010.
Canada	5% renewable content in petrol by 2010 and 2% renewable content in diesel fuel by 2012.
European Union	10% biofuel in 2020 set by European Commission in 2008.
Germany	2% ethanol and 4.4% biodiesel in 2007, increasing to 5.75% by 2010
Indonesia	2% of energy mix by 2010, 3% by 2015, and 5% by 2025. Seriously considering jatropha and cassava.
Malaysia	EnvoDiesel in all fuel stations and industrial sectors from 2008 (unsuccessful). Implement the mandatory use of biofuel for vehicles in 2011.
Thailand	5% and 10% replacement of diesel in 2011 and 2012 respectively.
UK	5% biofuel energy content by 2020.
US	Energy Independence and Security Act 2007 mandate a significant increase in biofuels use by 2020.

Malaysia's richness in oil palm is the primary driving force for its development of biodiesel industry. Malaysia is one of the world's major producers of oil palm and produced 17.56 million tons of palm oil in 2009. Therefore, Malaysia does not need to rely on foreign import for raw materials to develop its own biodiesel industry. Furthermore, using raw materials from own plantations will enable biodiesel developers to control the cost and quality of the biodiesel production more efficiently [49]. Hence, development of biodiesel in Malaysia had been growing by leaps and bounds. As the biggest producer and exporter of palm oil and palm oil products, Malaysia plays an important role in fulfilling the growing global need for oils and fats in general. Malaysia has positioned himself in the right path to utilize biofuel as a source of renewable energy and this can act as an example to other countries in the world that has huge biomass feedstock. The current installed biodiesel production capacity in the country is about 10.2 million tons [50]. There are many active biodiesel plants installed in year 2008 with a total annual biodiesel installed capacity of 1.2 million tons as shown in Table 16 [47]. An additional four biodiesel plants with combined annual capacity of 190 ktons are expected to commence commercial production by the end of year 2009 [51].

Table 16
Active biodiesel plants in 2008 [47].

No.	Plant location	Number of plants	Plant capacity (ktons/year)
1	Pasir Gudang, Johor	4	630
2	Lahad Datu, Sabah	2	300
3	Kuantan, Pahang	1	200
4	Ipoh, Perak	1	200
5	Teluk Panglima Garang, Selangor	1	150
6	Setiawan, Perak	1	60

The use of biodiesel as internal combustion engine fuels can play a vital role in helping the developed and developing countries to reduce the environmental impact of fossil fuels. Based on five strategic thrusts, the national biofuel policy will help the country to spell out a comprehensive framework and concrete initiatives for the use of biodiesel in Malaysia [49]. This policy is expected to reduce the dependency of petroleum and diesel. At the same time, it is also in line with the global efforts to reduce the greenhouse gasses. All these factors will contribute to biodiesel development especially palm oil based biodiesel.

5. Conclusion

The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. Road transport has dominated global oil consumption and is one of the fastest growing energy users in the last few decades. Consequently, greenhouse gas emissions from this sector have also risen in an alarming rate. As the Malaysian economy grew rapidly in recent year transportation becomes a vital contribution to economic growth and improvement of living standard. Transportation sector alone accounts for 36% of total energy consumption and the trend is still moving upwards. The motor ownership and motorization rate have increased significantly every year, thereby increasing the final consumption to 16.4 Mtoe in 2008. However, this sector is a major user of fossil fuels and contributes largely to emission. It is revealed that nearly 24 million tons of CO_2 were emitted in 1995 and increased to 50 million tons in 2008. Therefore, there is urgent need to adopt suitable energy policy to balance the energy demand and reduce the emission in this sector.

There are many policies implemented for road transport to reduce fuel consumption such as fuel economy standard, fuel economy label and fuel switching. It is found that mandatory implementation of fuel economy is an effective tool in controlling energy demand and greenhouse gas emission from transportation sector in many countries. On top of that, fuel switching to alternative renewable fuel can solve the scarcity of fossil fuel consumption. Biodiesel is gradually gaining acceptance in the market as an environmentally friendly alternative diesel fuel. Malaysia has huge potential for palm oil base biodiesel production and plays a role to reduce the environmental impact of fossil fuel. However, the use of inedible vegetable oils as an alternative fuel for diesel engine is accelerated by the need of edible oil as food and the reduction of biodiesel production cost. Therefore, jatropha and calophyllum inophyllum have great prospect as feedstock for biodiesel in Malaysia. Apart from that, various aspects must be examined and overcome before biodiesel can be established and continue to mature in the market. This study serves as a guideline for further investigation and research in order to implement and improve the transportation sector.

Acknowledgements

The author would like to express his acknowledgements to the Ministry of Higher Education of Malaysia and University of Malaya, Kuala Lumpur, Malaysia for the financial support under HIR research fund (D000015-16001), PPP research fund (PS092-2009B) and the Fellowship Scheme University of Malaya.

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